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CA R H NEYNABER ET AL. 14 MAY 86 AFOSR-TR-86-0519
F49620-85-C-0070

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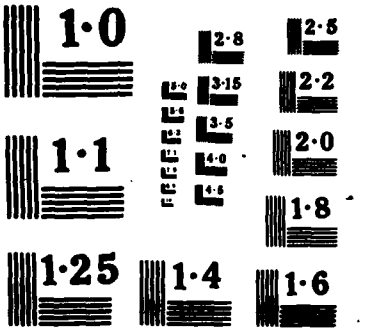
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# AD-A170 859 DOCUMENTATION PAGE

| | |
|---|---|
| 1a. R<br>Unclassified | 1b. RESTRICTIVE MARKINGS |
| 2a. SECURITY CLASSIFICATION AUTHORITY | 3. DISTRIBUTION/AVAILABILITY OF REPORT<br>Approved for public release; distribution unlimited |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S) | 5. MONITORING ORGANIZATION REPORT NUMBER(S)<br>AFOSR-TR- 86-0519 |
| 6a. NAME OF PERFORMING ORGANIZATION<br>La Jolla Institute | 6b. OFFICE SYMBOL (If applicable) |
| 6c. ADDRESS (City, State and ZIP Code)<br>P.O. Box 1434<br>La Jolla, CA 92038 | 7a. NAME OF MONITORING ORGANIZATION<br>USAF, AFSC, AFOSR/NP |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION | 8b. OFFICE SYMBOL (If applicable) |
| 8c. ADDRESS (City, State and ZIP Code) | 7b. ADDRESS (City, State and ZIP Code)<br>NP/Bldg. 410<br>Bolling Air Force Base<br>Washington, D.C. 20332 |
| | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER<br>F49620-85-C-0070 |
| | 10. SOURCE OF FUNDING NOS. |

| PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT NO. |
|---|---|---|---|
| 61102F | 2301/A | A4 | |

11. TITLE (Include Security Classification) (Unclassified)
Low-Energy Collisions of Excited Atoms

12. PERSONAL AUTHOR(S)
Neynaber, Roy H., Tang, Sheng Y.

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Yr., Mo., Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM 5/1/85 TO 4/30/86 | 86/5/14 | 5 |

16. SUPPLEMENTARY NOTATION

| 17. COSATI CODES | | | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) |
|---|---|---|---|
| FIELD | GROUP | SUB. GR. | Ion-pair production, chemi-ionization, cross sections, molecular beams, reaction rates |
| | | | |
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A summary of research performed under AFOSR Contract No. F49620-85-C-0070 is given. The contract covered the period 1 May 1985-30 April 1986. The report describes molecular-beam studies of ion-pair production, chemi-ionization, and measurements of the fraction of excited Na atoms in a composite beam or gas of ground-state and excited Na atoms. Some of the experiments involved laser excited Na as a reactant. Included are investigations of excited Na-Na, Na-Cl, metastable He-Li, Li-Cs, and Li-excited Na systems.



| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT | 21. ABSTRACT SECURITY CLASSIFICATION |
|---|---|
| UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☒ DTIC USERS ☐ | Unclassified B |

| 22a. NAME OF RESPONSIBLE INDIVIDUAL | 22b. TELEPHONE NUMBER (Include Area Code) | 22c. OFFICE SYMBOL |
|---|---|---|
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DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE. Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

## PROGRAM

Selected ion-pair production, chemi-ionization, and resonant and near-resonant charge-transfer reactions involving excited atoms will be experimentally studied in a range of relative energy from thermal, or threshold, to several hundred electron volts. Reactants of the processes include metastable rare-gas atoms, rare-gas ions, halogen atoms, ground-state and excited alkali atoms and alkali ions. Reactions leading to $Li^-$ are of special interest. The studies will be conducted in merging-beams and beam-gas apparatuses. A laser system will be used in conjunction with this equipment for experiments involving some excited atoms such as Na ($3\,^2P_{3/2}$). Cross sections as a function of collision energy, threshold behavior where applicable, and product-energy distributions will be measured. Existing theories, such as the Landau-Zener-Stueckelberg curve-crossing model for ion-pair production and the Demkov approach for near-resonant charge transfer, will be used to explain the observed data. Attempts will be made to modify these theories to account for discrepancies, new theories will be discussed where possible and the need for additional theoretical effort will be noted.



## ACCOMPLISHMENTS

The research accomplished on Contract F49620-85-C-0070 for the period 1 May 1985 - 30 April 1986 is cited below.

1. We prepared a manuscript of our measurements of the laser excited Na atoms in a fast (keV) beam entitled "Fractional Determination of Excited Atoms Produced by Collinear Laser and Fast Na Beams." This is the first measurement of this type. The paper has been published.

2. We have succeeded in partially exciting Na vapor in a cell with a laser and in measuring the excitation. A paper has been published on the subject.

3. We have measured absolute and relative cross sections, Q, for the ion-pair production (IPP) process $Na + Cl \rightarrow Na^+ + Cl^-$. The results can be explained by a theory of Faist and Levine which employs a modified Landau-Zener-Stueckelberg model. We have used this reaction to measure the fraction, $f^*$, of $Na^*$ produced in a vapor of Na (see # 2) by a laser, where $Na^*$ represents excited Na in the $3p\ ^2P_{3/2}$ state. The $f^*$ is obtained by measuring the $Cl^-$ product with the laser on and off. The technique works because the reaction proceeds with a ground-state (GS) Na reactant but not with a $Na^*$ reactant. A paper has been published.

4. Using the methods we have developed for laser excitation of Na beams and vapors, we have measured absolute and relative Q for the IPP reactions $Na^* + Na \rightarrow Na^- + Na^+$ and $Na + Na \rightarrow Na^- + Na^+$. The relative energy W of the measurements was in the range $500 \leq W \leq 2750$ eV. The results clearly show that IPP is greatly enhanced by exciting the Na. The Q that were actually measured are given below:

$$Na + Na \xrightarrow{Q_1} Na^- + Na^+ \quad (1)$$

$$Na + Na \xrightarrow{Q_2} Na^+ + Na^{-*} \quad (2)$$

$$Na_a^* + Na_b \xrightarrow{Q_3} Na_a^+ + Na_b^- \quad (3)$$

$$Na_a^* + Na_b \xrightarrow{Q_4} Na_a^- + Na_b^+ \quad (4)$$

$$Na_a^* + Na_b \xrightarrow{Q_5} Na_a^+ + Na_b^{-*} \quad (5)$$

$$Na_a^* + Na_b \xrightarrow{Q_6} Na_a^{-*} + Na_b^- \quad (6)$$

The subscripts a and b identify a specific atom and relate each product to its parent. The Na, $Na^+$ and $Na^-$ represent GS particles. The $Na^{-*}$ is excited $Na^-$ in the $3s3p\ ^3P$ state and is a so-called shape resonance with a very short ($<10^{-14}$ s) half life. A paper has been submitted for publication.

5. We have studied collisions of $He^*(2\,^3S,\ 2\,^1S)$ with Li. The $He^*$ represents a composite of 13% $He(2\,^1S)$ and 87% $He(2\,^3S)$. Absolute and relative Q have been measured in a range of W from 150 to 1500 eV for the IPP of $He^+ + Li^-$ and from 0.01 to 500 eV for chemi-ionization (CI) (i.e., Penning ionization and associative ionization). The relatively small ($< 1$ Å$^2$) and monotonically increasing Q with W for IPP that was obtained can qualitatively be explained on the basis of poor coupling in at least the first step of a ladder climbing process between the incoming covalent and outgoing ionic potentials. Attempts to observe signals for IPP of $He^- + Li^+$ were obscured by noise. The CI results can be considered as those for $He(2\,^3S)$ on the basis of similar experiments by others. Information obtained for CI includes: i) the Penning ionization reaction is directed with most of the $Li^+$ scattered in the incident Li direction, ii) the $He^*$-Li system is attractive with a measured well depth of 0.73 eV, and iii) the Q for total ionization varies as $W^{-0.34}$. Similarities to the $He^*$-$He^*$ system are observed. A manuscript is being prepared for publication.

6. We are presently studying the reaction $Li + Cs \rightarrow Li^- + Cs^+$. This is the second of a three-step process which is advocated by some for production of Li beams of interest to the Air Force. We have not found relative and absolute Q for this reaction in the literature, and so we are making an effort to correct this.

7. We have made some brief studies of the reactions $Li + Na^* \rightarrow Li^-(Li^+) + Na^+(Na^-)$ and $Li + Na \rightarrow Li^-(Li^+) + Na^+(Na^-)$ in which a fast (keV) beam of Li passes through a vapor of GS Na or $Na^*$ (laser excited). The W was in the range 766 to 4214 eV. As expected, the production of a $Li^-$ beam is greatly assisted by laser excitation of Na. The first reaction is an alternate to the Li-Cs reaction discussed in #6 above for producing Li beams. We will continue these studies and compare the Li-Cs and Li-$Na^*$ reactions.

## PUBLICATIONS

1. D. P. Wang, S. Y. Tang and R. H. Neynaber, "Fractional Determination of Excited Atoms Produced by Collinear Laser and Fast Na Beams," J. Phys. B18, L5 (1985).

2. D. P. Wang, S. Y. Tang and R. H. Neynaber, "Ion-Pair Production in Collisions of Na and Cl." J. Phys. B18, L513 (1985).

3. S. Y. Tang, D. P. Wang and R. H. Neynaber, "Measurements of the Population of Excited Na Atoms in Laser-Excited Na Vapor," J. Phys. B19, L25 (1986).

## TALKS

1. D. P. Wang, S. Y. Tang and R. H. Neynaber, "Fraction of Laser Excited Atoms in Na Vapor and Fast Na Beams," Conference on the Dynamics of Molecular Collisions, Snowbird, Utah (1985).

2. R. H. Neynaber, S. Y. Tang and D. P. Wang, "Ion-Pair Production in Collisions of Na with Cl and Br," XIV International Conference on the Physics of Electronic and Atomic Collisions, Stanford University, p. 369 (1985).

3. S. Y. Tang, D. P. Wang and R. H. Neynaber, "Ion-Pair Production and the Effect of Laser Excitation in Na-Na Collisions," ibid., p. 370 (1985).

4. D. P. Wang, S. Y. Tang and R. H. Neynaber, "Measurements of Laser Excited Atom Population in Na Vapor and Fast Na Beams," ibid., p. 666 (1985).

## PARTICIPANTS

The participants in the research described above are Dr. R. H. Neynaber, Dr. S. Y. Tang and Mr. D. P. Wang (graduate student).

## USE OF RESULTS

The Air Force Weapons Laboratory at Kirtland Air Force Base is interested in our results which are applicable to the production of fast neutral particle beams of light masses. A copy of this report is being sent there to Capt. G. McHarg of Space Applications/AWYS.





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